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#### SPECIFICATION

1. Title of the Invention:

PLASTIC BASED OPTICAL FIBER

2. Claim

A plastic based optical fiber comprising a core made of an organic polymer having a cross-linked structure with a refractive index of 1.41 or more, and a clad layer made of a substantially transparent organic polymer provided at an outer circumference of the core and having a refractive index 0.01 or more as low as the refractive index of the core, wherein a light transmissible body made of a transparent organic polymer or inorganic glass having a Rockwell hardness of 40 or more is joined at least at one end of the optical fiber.

### 3. Detailed Description of the Invention

#### [Technical Field of the Invention]

The invention relates to a plastic based optical fiber having a core component made of a resin being excellent in flexibility and having a cross-linked structure that is excellent in environmental durability. The invention particularly relates to a plastic based optical fiber that is improved in injury resistance at the end of the fiber.

#### [Description of Related Art]

Although inorganic glass based fibers having an excellent light transmission property over a wide wavelength region have been known in the art, light transmission fibers using synthetic resins as base materials have been developed since the glass fiber has poor processibility and low bending stress while being expensive. The light transmission fiber made of the synthetic resin is obtained by manufacturing a fiber having a core-clad structure, wherein a polymer having a large refractive index and good light transmittance is used as a core, and a transparent polymer having a refractive index smaller than that of the core is used as a clad layer. Amorphous materials are preferable as the polymers useful as core components having high light transmittance, and polymethyl methacrylate or polystyrene is usually used.

Among these polymers as the core component, polymethyl

methacrylate is industrially used as a core material of a high performance plastic based optical fiber due to its excellent transparency as well as mechanical and thermal properties and environmental durability.

However, even the plastic light transmission fiber using polymethyl acrylate as the core is not sufficient in flexibility. Since the plastic based optical fiber having a diameter of 1 mm or more is rigid and is readily broken, the plastic based optical fiber cannot sufficiently manifest its characteristics in the use such as a light guide that is required to have a large aperture for transmitting a large capacity of light. Accordingly, developments of flexible light transmission fibers having a large aperture are urgently required.

Since polymethyl methacrylate of the plastic light transmission fiber using polymethyl methacrylate as the core has a glass transition temperature of 100°C, the fiber cannot be used at all when the temperature of the environment of use is higher than 100°C. Furthermore, chemical resistance and water resistance are also poor. Therefore, use of the plastic based optical fiber is prevented from being expanded.

Japanese Unexamined Patent Laid-Open Nos. 57-88405 and 57-102604 have disclosed plastic based optical fibers using a silicone rubber as the core as plastic based optical

fibers for solving the problems as described above.

[Problems to be Solved by the Invention]

However, the optical fiber using the silicone rubber as the core as shown in the preceding inventions exhibit rubber elasticity while having a low hardness. In addition, although processing of both end faces of the fiber before the use of the optical fiber is inevitable, it is difficult to smooth the end faces. Furthermore, the clad is peeled from the core at the core/clad interface by processing or during the use, and dusts are invaded into the peeled interface to cause drawbacks of decreased light transmission characteristics.

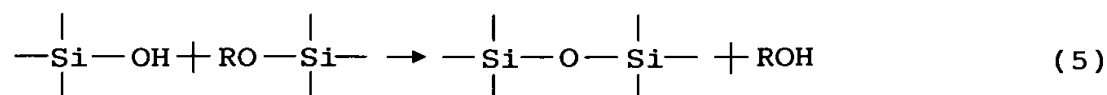
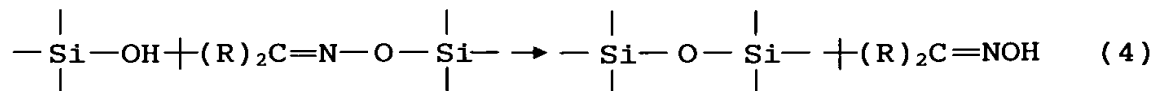
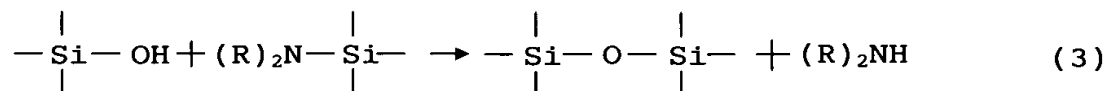
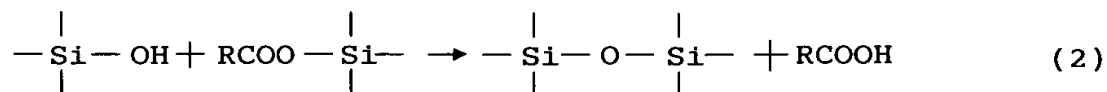
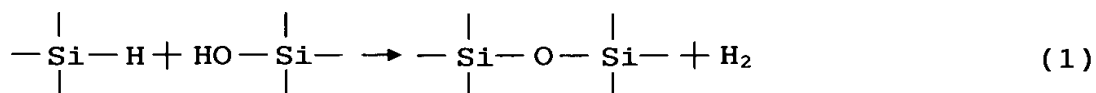
[Means for Solving the Problems]

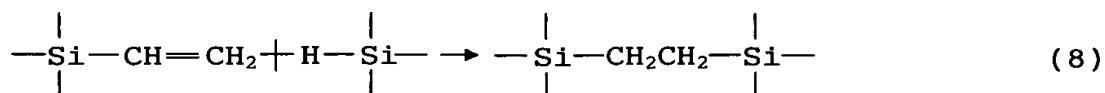
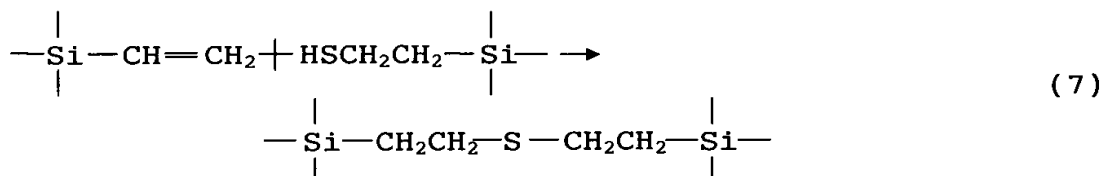
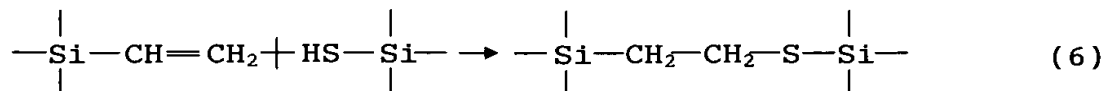
Accordingly, the inventors of the invention have developed a plastic based optical fiber using an organic polymer having a cross-linked structure as a core component that is free from the drawbacks as described above, thereby completing the invention.

The invention provides a plastic based optical fiber comprising a core made of an organic polymer having a cross-linked structure with a refractive index of 1.41 or more, and a clad layer made of a substantially transparent organic polymer provided at an outer circumference of the core and having a refractive index 0.01 or more as low as the refractive index of the core, wherein a light transmissible

body made of a transparent organic polymer or inorganic glass having a Rockwell hardness of 40 or more is joined at least at one end of the optical fiber.

While silicone resins, bisallyl carbonate resins, allylphthalate resins and acrylic resins having a cross-linked structure can be used in the invention as the organic polymer constituting the core having the cross-linked structure, the cross-linked organic polymers having a tensile strength of 0.5 kg/cm<sup>2</sup> or more and an elongation ratio of 20% or more are preferable among them considering easy handling of the optical fiber of the invention. The silicone resin is particularly preferable among the resins. The modes of the cross-linking reaction available are as follows:





(R denotes an hydrogen atom or an arbitrary monovalent organic radical).

The cross-linked organic polymer constituting the core is required to have a refractive index of 1.41 or more, and the refractive index may be appropriately selected depending on the numerical aperture required for the plastic based optical fiber of the invention.

The cross-linked organic polymer constituting the core may be prepared by cross-linking the polymer by an addition reaction using a peroxide, light and Lewis acid catalyst.

The component of the clad layer available in the invention should be a substantially transparent organic polymer (preferably thermoplastic polymer) having a refractive index 0.01 or more as small as the refractive index of the core component polymer. When the refractive index difference is less than 0.01, the numerical aperture of the optical fiber becomes small with a quite large

transmission loss. When the refractive index of the clad layer is larger than the refractive index of the core, the light is not transmitted at all.

Examples of the low refractive index thermoplastic resins to be used as the clad layer of the plastic based optical fiber of the invention include polytetrafluoroethylene ( $n_d = 1.35$ ), tetrafluoroethylene/perfluoroalkylvinylether copolymer ( $n_d = 1.34$  to  $1.36$ ), tetrafluoroethylene/hexafluoropropylene copolymer ( $n_d = 1.34$ ), polychlorotrifluoroethylene ( $n_d = 1.425$ ), tetrafluoroethylene/ethylene copolymer ( $n_d = 1.40$ ), polyvinyl fluoride ( $n_d = 1.42$ ), polyvinylidene fluoride ( $n_d = 1.47$ ) and tetrafluoroethylene/vinylidene fluoride ( $n_d = 1.38$  to  $1.42$ ). Other fluorinated polymers such as various polymers and copolymers of fluorinated alkylmethacrylate ( $n_d = 1.38$  to  $1.48$ ) and blends of polyvinylidene fluoride and polymethyl methacrylate ( $n_d = 1.43$  to  $1.48$ ) as well as poly-4-methyl-1-pentene ( $n_d = 1.46$ ) and polymethyl methacrylate ( $n_d = 1.49$ ) may be used when the core has a high refractive index.

While the plastic based optical fiber of the invention is manufactured with a core diameter in the range of 5 to 3000  $\mu\text{m}$ , a light transmission passageway with an extra-large diameter of larger than 3000  $\mu\text{m}$  up to about 50 mm is possible since the optical fiber is excellent in flexibility.

A thickness of the clad layer of 1  $\mu\text{m}$  or more is necessary for favorable light transmission by taking advantage of total internal reflection of the optical fiber obtained. The upper limit of the thickness of the clad layer may be appropriately selected depending on the object of use of the optical fiber.

The transparent organic polymer joined at least at one end of the optical fiber of the invention is required to have a Rockwell hardness of 40 or more as determined according to ASTM D785M scale. When the hardness is less than 40, processibility of the optical fiber becomes poor while being damaged by the vessel during the use to cause a decrease of light transmission. Examples of the transparent organic polymer having a hardness of 40 or more include polystyrene, polymethyl methacrylate, polybenzyl methacrylate and polycarbonate, and the shape thereof available is a spherical convex lens and concave lens, a columnar convex lens and various other shapes. While the methods for joining the light transmissible body to the optical fiber comprise joining by bonding as shown in Fig. 1(a) and joining by inserting the most part of the light transmissible body into the clad layer as shown in Fig. 1(c), the most desirable method is to insert a part of the light transmissible body into the clad layer at the tip of the optical fiber as shown in Fig. 1(b). In this drawing, the



reference numeral 1 denotes the core having a cross-linked structure, the reference numeral 2 denotes the clad, and the reference numeral 3 denotes the light transmissible body. Such joining method as described above permits the optical fiber to be favorably joined to the light transmissible body, and the drawback of peeling at the core-clad interface during processing of the tip of the optical fiber can be almost completely eliminated.

The method for manufacturing the plastic based optical fiber of the invention desirably comprises forming the organic polymer constituting the clad layer into a hollow fiber, injecting a fluid of a precursor for forming the cross-linked organic polymer as the core component into the hollow fiber, and allowing the cross-linking reaction to start after confirming that the fluid is standing still. The light transmissible body may be joined while the core component is fluid before the cross-linking reaction, or may be joined after the cross-linking reaction.

It is necessary for reducing light transmission loss of the light transmission fiber that the precursor for forming the core is purified by filtering before forming the core with a membrane filter having a pore diameter of 0.05 to 10  $\mu\text{m}$ , preferably 0.05 to 1  $\mu\text{m}$ , so that substantially no bright spots are observed by irradiating a visible laser light. It is easy to reduce the transmission loss of a visible light

having an wavelength in the range of 600 to 700 nm to less than 1000 dB/km, and the transmission loss can be further reduced to less than 100 dB/km by completely preventing the precursor from being mingled with foreign substances and dusts.

[Advantages]

The plastic based optical fiber of the invention is a high performance and highly reliable light transmission fiber having flexibility, heat resistance, cold resistance, chemical resistance and vibration resistance exceeding the ranges of the conventional plastic based optical fiber. Light communication in a length of more than several hundreds meters is possible using the plastic based optical fiber even under a quite severe environment. The core is prevented from being peeled from the clad at the interface when the end faces are processed, and the optical fiber is excellent in damage resistance, making the invention to be quite significant.

The plastic based optical fiber of the invention is particularly suitable for optical control in a severe environment such as engine rooms of automobiles, ships and airplanes.

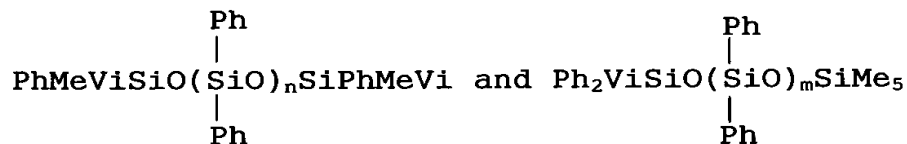
The invention will be describe in detail hereinafter with reference to examples. In the examples, Me denotes a methyl radical, Ph denotes a phenyl radical, an Vi denotes a

vinyl radical.

"Parts" and "%" in the examples all represents "parts by weight" and "% by weight (wt%)", respectively, and the viscosity was measured at 25°C.

Example 1

A mixture of



with a viscosity of 700 centistokes was filtered with a tetrafluoroethylene filter with a pore size of 0.1  $\mu\text{m}$ . Into 95.0 parts of the filtrate obtained above, 5.0 parts of  $\text{PhSi}-(\text{OSiPh}_2\text{H})_3$  and 5 ppm of platonic chloride dissolved in 2-ethylhexanol, each being filtered with a tetrafluoroethylene filter with a pore size of 0.1  $\mu\text{m}$ , were mixed in a clean room, and the mixture was defoamed to prepare a precursor for the core component.

Polysiloxane obtained by heating the precursor at 150°C for 2 hours had a refractive index ( $n_d$ ) of 1.51, tensile strength of 2  $\text{kg/cm}^2$  and elongation ratio of 60%.

On the other hand, a hollow fiber with an inner diameter of 9 mm and outer diameter of 10 mm was obtained by melt-extrusion of a 85/15 copolymer ( $n_d = 1.34$ ) of tetrafluoroethylene/hexafluoropropylene from a hollow fiber forming nozzle at 325°C.

Two strings of the hollow fiber were cut into a length of 100m. One end of each fiber was connected to a vacuum pump, and the precursor for forming the core component was filled into the hollow fiber from the other end. Columnar concave plastic lenses having a Rockwell hardness of 80, an outer diameter of 9.3 mm and a length of 10 mm were inserted into both ends of one of the hollow fiber as shown in Fig. 1(b) so that air is not incorporated into the joint between the precursor and columnar convex plastic lens. No such treatment was applied to the other hollow fiber.

The plastic based optical fibers were manufactured by completing the cross-linking treatment by heating the two strings of the hollow fiber in which the precursor was filled at 150°C for 1 hour.

The two kinds of the plastic based optical fiber obtained were cut into a length of 5 m with a knife, and the luminous energy of the projected light from each fiber was measured by attaching the fibers to the same light source. The convex lens side was attached to the light source with respect to the optical fiber having the convex lens.

The luminous energy of the projected light was 2.3 times brighter than the luminous energy of the optical fiber having no convex lens.

#### Example 2

The optical fiber was obtained by the same method as in

Example 1, except that the columnar concave lens in Example 1 was replaced with a transparent glass ball with a diameter of 9.5 mm, and the glass balls were attached at both ends of the fiber.

The inside of a dark box heated at 160°C was illuminated using the optical fiber, finding that brightness in the box did not change after 24 hours.

#### 4. Brief Description of the Drawings

Figs. 1(a), 1(b) and 1(c) show cross sections of the plastic based optical fiber of the invention.

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